Preprint
UCRL-JC-153490

# Update from the "Radiochemistry at RIA" Symposium held March 27, 2003 at the 225th American Chemical Society Meeting in New Orleans, LA

*M.A. Stoyer, P.F. Mantica*

This article was submitted to
American Nuclear Society Conference
San Diego, CA
June 1-5, 2003

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

**May 27, 2003**

**Update from the "Radiochemistry at RIA" Symposium held March 27, 2003 at the 225th American Chemical Society Meeting in New Orleans, LA**


Mark A. Stoyer

*L-231, Lawrence Livermore National Laboratory, Livermore, CA 94550*

Paul F. Mantica

*NSCL, Michigan State University, South Shaw Lane, East Lansing, MI 48824*


## INTRODUCTION

The scientific case for a new high-luminosity Radioactive Ion Beam (RIB) Facility capable of accelerating essentially the entire chart of the nuclides has been established over more than a decade.[1-5] Preliminary experiments at new facilities [6] are promising as the frontier of RIB research continues to expand at a fast rate. Radiochemical experiments that could benefit many areas of research, from the basic science of astrophysics and heavy element research, to the applied science of Stockpile Stewardship and medical isotope production, are now for the first time being seriously discussed for a RIB facility. This paper attempts to highlight some areas of research which may be significantly enhanced should a premier radiochemical facility be co-located at a RIB accelerator facility such as the Rare Isotope Accelerator (RIA). The purpose of the symposium was to gather together experts in a variety of fields to discuss the harvesting of radionuclides and its potential benefits to research in the heavy element research, medical isotope production, Stockpile Stewardship Program (SSP), environmental research, astrophysics and educational fields. Preliminary ideas as to the engineering features required for such a facility at RIA, to generate, handle, store and use isotopes of interest potentially containing very high levels of radioactivity, were discussed. Many of the presentations are accessible via http://www.cem.msu.edu/~mantica/radio-ria/.

## PRESENTATION HIGHLIGHTS

The symposium began with overview talks on the technical specifications and pre-conceptual-design engineering layout of the RIA facility itself by Richard York (see Figure 1) and the physics RIA is designed to address by Robert Janssens.

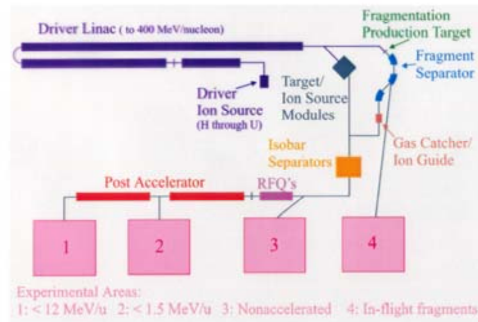


Fig. 1. Schematic of the main components of RIA. This design features both the projectile fragmentation and isotope on-line production methods.

The design of RIA itself is meant to be flexible in not only the numbers of beams available, but also the energies of those beams available. Multiple experimental areas are planned and the possibility of running multiple experiments at a time with the generated beams is an option. Note that the RIA project is still awaiting DOE approval of mission critical need, the CD0 design phase.

Physics highlights include the investigation of isotopes so far produced copiously only in the cosmos, novel nuclear structures and nuclear shapes, doubly magic nuclei, N=Z nuclei, studies of neutron/proton interactions and pairing effects and investigation of isotopes at the drip lines. An overview of potential harvesting locations and a notional idea of a co-located neutron facility (see Figures 2 and 3) was presented by Larry Ahle—highlighting the need for rapid radiochemical separations and the ability to irradiate targets with neutrons quickly. A neutron source with 10 keV < $E_n$ < 20 MeV is envisioned for RIA.

Finally, Ken Moody gave an overview of facilities capable of handling large amounts of radioactivity. Several reminders of good, bad and ugly engineering features for remote manipulator cells were provided and should serve as lessons learned for future design of this facility (see

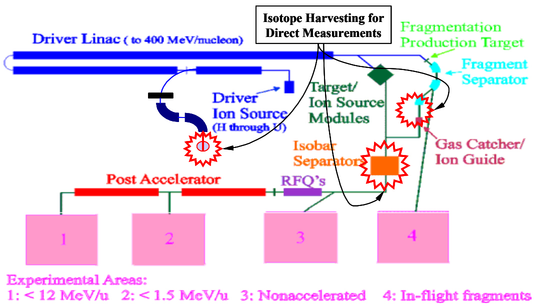


Fig. 2. Several locations for "harvesting of isotopes can be identified at the generic RIA facility.

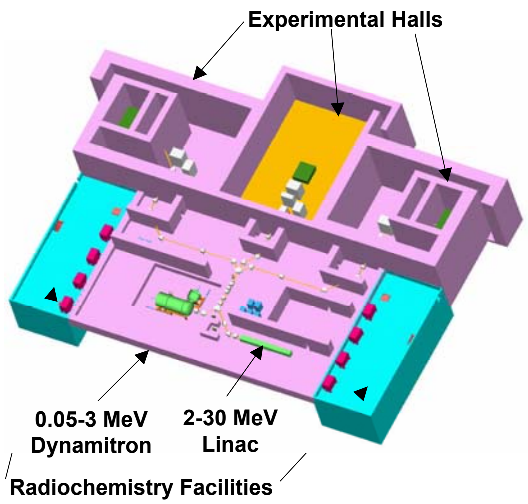


Fig. 3. Preliminary design for co-located neutron generation facilities spanning the neutron energy range of approximately 100 keV to 30 MeV. As was pointed out during the symposium, the design of the radiochemistry facilities was not past the "blue lego" stage.

Figure 4). The third from worst thing that can happen in a manipulator cell is a containment breach. Next worse is an overpressure of the cell (many operations are performed with compressed air). The worst thing that can happen in a remote manipulator cell is a fire. Planning ahead, proper design of tools and widgets, and built-in redundancy of critical systems is essential for smooth operations. Some target handling and processing facilities could be co-located within a radiochemical remote manipulator facility. Ideas for ergonomically correct, radiation resistant, reliable remote manipulator cells, as well as an underground transport system were discussed.

Fig. 4. Photo of a cracked manipulator cell window after inadvertent application of pressure from a manipulator. An example of the bad things that can happen when certain safety features are not engineered into the system.

### Medical Aspects

Tom Ruth and Jose Alonso discussed concepts for production of isotopes with medical applications at a RIB facility such as RIA. It was concluded that RIA, while not the facility for long-term reliable production of radioisotopes suitable for therapy, would be the facility to define more viable production methods of radioisotopes in high specific activity and also to produce research quantities of more exotic potential therapeutic radionuclides. A list of about 20 candidate radionuclides for radioimmunotherapy was presented. However, in spite of the recognized limitations of RIA, namely difficult scheduling requirements, availability issues and reliability, the consensus was that RIA radioisotope production would be an important component of biomedical research and health care in N. America. An alternative potential technique, using high currents of light ions, could also be investigated at RIA.

### Educational Aspects

Sue Clark eloquently discussed the abysmal state-of-affairs for the training of new radiochemists, nuclear chemists and nuclear physicists. The numbers of PhD's awarded in nuclear chemistry/radiochemistry are down from about 23/year in the 1970's to about 7/year in the 1999-2002 time period. At the same time, DOE's nuclear workforce has aged from an average age of about 30-34 in 1988 to an average age of 45-49 in 2002. Clearly with new large projects being proposed and planned, the training of radiochemists is far short of what will be required.

It is hoped that a re-invigoration of nuclear chemistry and radiochemistry educational efforts will result from exciting projects with significant numbers of scientists in these disciplines required such as RIA, the National Ignition Facility (NIF), or the Spallation Neutron Source (SNS). The vast majority of the round table discussion period at the end of the symposium was devoted to discussing this conundrum of support for educational activities in radiochemistry and nuclear chemistry; namely, the reluctance of universities to hire new faculty in these fields without promise of external long-term financial support, and the inability of traditional funding agencies such as the Department of Energy (DOE) to provide funds because of specific mandates that exclude them from the educational/university domain. It was recognized that programs such as the Academic Alliance for the SSP and the ACS sponsored Nuclear Chemistry summer schools at San Jose and Brookhaven are small efforts in the correct direction designed to provide such funding, which is ultimately of recruiting benefit to DOE in the long run.

**SSP**

Talks were given by Bob Rundberg, Lee Bernstein, Dave Vieira and Peggy McMahan on existing efforts or planned experiments with SSP applications. Bob discussed capture cross-section measurements just starting using a new 159 element detector array of $BaF_2$ detectors called DANCE (see Figure 5) located at the LANL lower energy neutron facility at LANSCE.

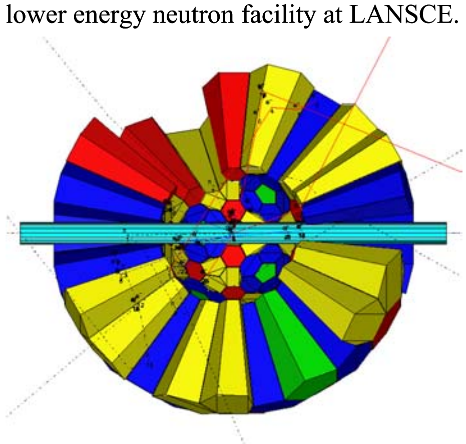

Fig. 5. Cut-away CAD drawing of the DANCE array.

A long list of nuclides for capture cross-section measurements has been identified that will benefit the astrophysical community (s-process waiting nuclei), SSP and basic science research. Lee Bernstein discussed using surrogate reactions to measure cross-sections of interest to SSP (see Figure 6 for an example). Many such required cross-sections are on unstable radioactive nuclei, and there exists no other experimental method to measure them. Measurements of cross-sections in various mass regions will enable nuclear models to be improved and greatly improved cross-section sets to be constructed for interpretation of data from past nuclear events.

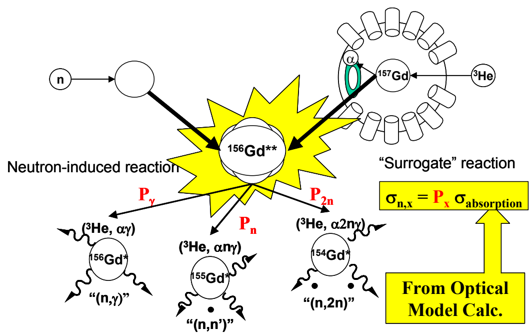


Fig. 5. An example of how charged particle reactions can be used to populate the same nuclear levels with approximately the same spin distribution as neutron-induced reactions. This method may one of the only ways to measure cross-sections on otherwise inaccessible nuclides.

Dave Vieira talked about obtaining a trapping capability at RIA, for atomic and nuclear physics measurements on radioactive isotopes, such as improved mass measurements, decay studies, etc. The capability of trapping nuclei is complementary to stopping isotopes of interest on a foil or in a gas for further study.

A specific cross-section measurement, namely, the $^{89}Zr(n,2n)^{88}Zr$ reaction, was discussed by Peggy McMahan—an Academic Alliance project with LBNL and LLNL participants. This tour de force experiment requires production of the $^{89}Zr$ via the $^{89}Y(p,n)$ reaction, chemical separation of the produced $^{89}Zr$ from Y target, neutron irradiation of the $^{89}Zr$ with 14-MeV neutrons from the Rotating Target Neutron Source (RTNS) and gamma-ray counting of the resultant $^{88}Zr$ after a suitable “cooling” period following neutron irradiation to allow the $^{89}Zr$ to decay. Careful consideration of background and alternative production reactions that would interfere with the cross-section measurements was made.

### Astrophysics Research

Jeff Blackmon and John D'Auria discussed experiments of interest to the astrophysical scientific community. Since reactions involving radioactive nuclei are crucial for the synthesis of elements heavier than iron, measurements on radioactive targets are an efficient method for obtaining critical nuclear data for understanding this synthesis process. Slow neutron capture (s-process) waiting point nuclides might be investigated at RIA, although only a few isotopes compete with reactor-based activation techniques. Production of targets of relatively long-lived proton-rich nuclei, for measuring data on p-process nucleosynthesis, is competitive at RIA. In addition, RIA may address certain isotopes of importance to rapid neutron capture (r-process) nuclei. Arguments for making more efficient use of RIA if multiple on-line isotope separators were available were made. It was also mentioned that significant research opportunities exist at the TRIUMF ISAC facility for research with radioactive nuclear beams today.

### Heavy Element Research

Irshad Ahmad discussed some nuclear structure and nuclear decay studies one might conceivably perform at RIA, based on past experiments in the heaviest nuclei. Decay studies of Cf nuclides have provided theorists with an interesting test-bed for nuclear models aimed at describing the behavior of the heaviest neutron and proton orbitals. The possibility of producing super-heavy elements (SHE) with secondary beams of neutron-rich nuclides was deemed too uncertain to predict until more cross-section measurements in the region could be measured. While the typical beam intensities of neutron-rich radioactive beams are much below the beam intensities currently used to investigate elements 114 and 116, if production cross-sections for SHE increase with neutron-rich beams, then some work might be possible in this interesting region—especially towards determining if the long-predicted "Island of Stability" can be populated directly.

## DISCUSSION

As mentioned previously, the issue of education dominated the discussion period. Several ideas on improving the situation were mentioned, including improving funding of undergraduate and graduate students at universities. The nuclear science educational infrastructure is in rapid decay through retirements and replacement of faculty positions in radiochemistry with other areas of chemistry.

Finally, the participants speculated on the most exciting aspects of RIA research that might be expected 4-5 years after completion of RIA construction. Significant advances in addressing the long-standing problems in astrophysics were generally thought to be the most forthcoming result from RIA.

## CONCLUSIONS

This symposium met its stated purpose of discussing the "harvesting" of radionuclides at RIA. The radiochemistry, chemistry, and physics that could be performed with beams or targets of radioactive isotopes were enumerated. The facilities required to generate, handle, store and use these isotopes are beginning to be discussed and specified. Many areas of radiochemical interest were identified. While the authors recognize it is a complex problem, this issue of training and educating radiochemists to work in such a facility co-located at RIA is urgent. It should be noted that the training period and the planned length of RIA construction time are approximately the same.

## ACKNOWLEDGEMENTS

This work was performed under the auspices of the U.S. Department of Energy by UC Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

## REFERENCES

1. *Proceedings of the 1st International Conference on Radioactive Nuclear Beams*, Berkeley (California), Oct. 1989 ed. by W.D. MYERS, J.M. NITSCHKE, E.B. NORMAN (World Scientific, Singapore, 1990).
2. *The IsoSpin Laboratory, Research Opportunities with Radioactive Nuclear Beams*, LALP 91-51 (1991).
3. *Proceedings of the 2nd International Conference on Radioactive Nuclear Beams*, Louvain-la-Nueve (Belgium), Aug. 1991 ed. by TH. DELBAR (Adam Hilger, Bristol, 1992).

4. *Proposal for Physics with Exotic Beams at HHIRF*, ed. by J.D. GARRETT and D.K. OLSEN, Physics Division, ORNL (1991).
5. *NUPECC Report on European Radioactive Beam Facility*, ed. by P. KIENLE (1993).
6. http://www.triumf.ca/isac/isac_home.html.